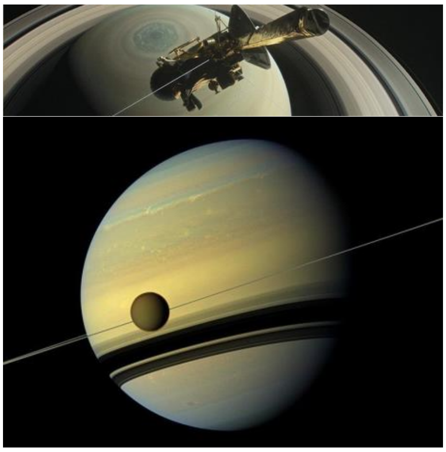
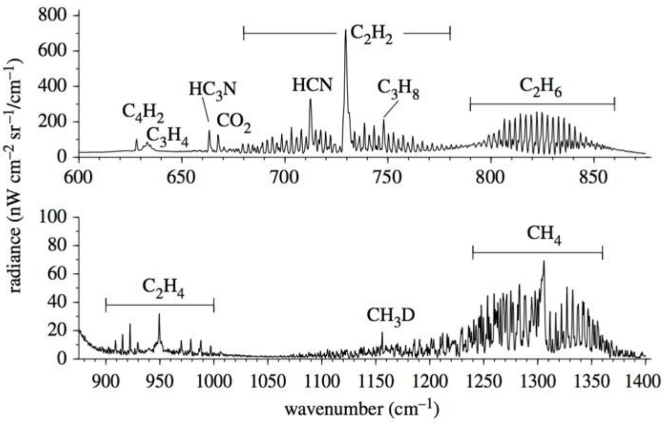
Exploring Saturn and Titan's atmosphere with infrared spectroscopy from the Cassini spacecraft

Supervisors: Nick Teanby + Jessica Irving (School of Earth Sciences)
Project Enquiries: n.teanby@bristol.ac.uk





Left. (top) Cassini passing over Saturn's north pole. (bottom) Cassini ISS image of Saturn, with its largest moon Titan in the foreground. Titan has a thick atmosphere and a similar surface pressure to Earth, so is often used as an early-Earth analogue.
Right. Example thermal infra-red spectrum of Titan from Cassini's CIRS spectrometer, which returned over a terabyte of spectra during the mission (2004-2017). Observations of gas emission peaks can be used to determine atmospheric composition and temperature. Such data can be used to probe atmospheric chemistry and dynamics, providing insight into the workings of planetary atmospheres.

Project Background

The solar system contains a wide variety of planetary atmospheres, from tenuous gas envelopes surrounding large icy satellites, to the thick atmosphere of organic-rich Titan, and the massive atmospheres the giant planets themselves[1]. The main technique used to probe composition and dynamics of these atmospheres is remote sensing and infra-red spectroscopy, where emission lines of trace gas species are used to derive profiles of temperature and composition[1,2]. These observations improve our understanding of how planets evolve and how planetary atmospheres work in general.

Project Aims and Methods

This PhD project will study the atmosphere of Saturn or its giant moon Titan using infrared spectroscopic observations from the Cassini spacecraft's Composite InfraRed Spectrometer (CIRS)[3] instrument. Cassini took millions of Saturn and Titan spectroscopic observations during its 2004-2017 Saturn-system tour and many of these observations remain unanalysed[4]. This project will focus on the more unusual and non-standard datasets to provide unique atmospheric information. Later in the project, there may also be opportunity to use observations from other facilities, such as the Atacama Large Millimeter/sub-millimeter Array (ALMA) or the James Webb Space Telescope[5].

Spectra will be analysed using radiative transfer methods with the NEMESIS[2] (FORTRAN) software or its sister-code ArchNEMESIS[6] (Python). Analysis starts from an atmospheric forward model based on existing knowledge along with gas spectroscopic parameters from laboratory studies. Inverse theory techniques are then then applied to iteratively adjust the model atmosphere to determine atmospheric temperature and composition that best fit both observed data and existing constraints. The derived physical and chemical state of the atmosphere is then used to develop interpretations for atmospheric chemistry and dynamics[7–9]. The size of the Cassini dataset means there is ample scope for the student to have input into the project direction after gaining suitable experience in the observations and analysis techniques. Titan will likely be the focus, but Saturn is also a possibility.

Candidate

Ideally a background in physics to MSc/MSci level. Strong interests in space exploration, planetary science, atmospheric physics, and numerical data analysis techniques are essential. Familiarity with scientific computing/programming would be a definite advantage as the main component of the project will be quantitative analysis of spectroscopic datasets using a combination of existing code and new code developed by the student.

Training

Skills will be built up mainly via independent study and one-to-one supervision, but could also include attendance of specific lecture courses and workshops (as required). The student will be expected to present results at national and international conferences, interact with national/international collaborators, and publish findings in high impact international journals. This will require excellent communication and written skills. The project will require the development of skills in atmospheric and planetary science, remote sensing, radiative transfer modelling, inverse theory, and numerical analysis. This will leave the candidate in an excellent position for a career in atmospheric/planetary science, or any field requiring numerical data analysis. The student will join the Earth Sciences Geophysics group, which covers a wide range of earth and planetary science research topics. Within this group they will be part of a small team studying planetary atmospheres.

References:

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3. Nixon, C. A. *et al.* Cassini Composite Infrared Spectrometer (CIRS) Observations of Titan 2004–2017. *Astrophys. J. Suppl. Ser.* **244**, 14 (2019).
4. Wright, L., Teanby, N. A., Irwin, P. G. J. & Nixon, C. A. Forward modelling low-spectral-resolution Cassini/CIRS observations of Titan. *Exp. Astron.* **57**, 15 (2024).
5. Nixon, C. A. *et al.* The atmosphere of Titan in late northern summer from JWST and Keck observations. *Nat. Astron.* **9**, 969–981 (2025).
6. Alday, J., Penn, J., Irwin, P. G. J., Mason, J. P. & Yang, J. archNEMESIS: an open-source Python package for analysis of planetary atmospheric spectra. Preprint at https://doi.org/10.48550/ARXIV.2501.16452 (2025).
7. Teanby, N. A. *et al.* The formation and evolution of Titan's winter polar vortex. *Nat. Commun.* **8**, 1586 (2017).
8. Teanby, N. A. *et al.* Seasonal Evolution of Titan's Stratosphere During the Cassini Mission. *Geophys. Res. Lett.* **46**, 3079–3089 (2019).
9. Wright, L. *et al.* Seasonal Evolution of Titan's Stratospheric Tilt and Temperature Field at High Resolution from Cassini/CIRS. *Planet. Sci. J.* **6**, 114 (2025).

Application deadline: 14.00 GMT, 25th Feb 2026

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